Telerobotics for Microsurgery

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I. INTRODUCTION

Surgeries of the eye, ear, face, 1)100(1" vessels and II ns system require fine and precise manipulation of small instruments. Surgeons performing these procedures work on tissue features of about fifty to a few hundred mic . in size and visualize the surgical field through a mi o scope. Current Practice in microsurgery requires 1111 . ur geon to manually manipulate instruments designed for specific parts of a procedure while viewing the instrument tips under the microscope.

A tool" that would greatly improve a surgeons Per formance in microsurgery practice is one that performs a function analogous to the microscope but for the m , chanical interaction between the surgeon and the patient The microscope amplifies the visual information from the surgical site to the surgeon. A tool that could scale (own the surgeon's hand motions to the surgical site would al low greater control of motions of surgical instruments a i so result in more precise microsurgery. This would allow the average SIII/,('(111 to perform at the level of those surgeons and allow the most skillful SIl'p,('L) II'to perform at an even higher level ["1].

The authors have 1)('('11 working with Steven ('lii l s, MD, a vitreo-retinal surgeon, to develop such a tool. The Robot Assisted MicroSurgery (R AMS) telerobotic sy tem (l('V('lo])('(l at JPL [3] is a prototype of" a system that will be completely under the manual control of a surgeon The system has a slave robot that will hold surgical instruments. '1'1](' slave robot motions replicate those of the surgeon's hand measured using a master input device with a handle shaped like the handle of a . urgical instrument. The surgeon commands motions for the instrument by moving the handle in the desired trajectories. The trajectories are measured, filtered, scaled (own and then used to drive the slave robot. A photograph of the RAMS system shown is 011 Figure 1.

II. DESCRIPTION

Engineering components of the system are shown on the drawing on Figure 2. Sub systems of the RAMS system are:

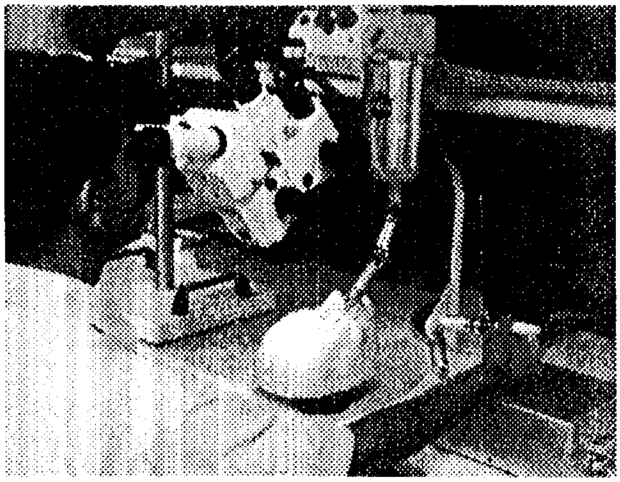

Fig. 1. RAMS slave robot system.

- the *mechanical sub-system*, including the motors, encoders, gear and cable drive systems, the links and joints of the slave robot and master input device,
- the *electrical sub system*, including safety electronics,
- the *servo control subsystem*, including the servo-control software and communication and shared memory software, and
- the *kinematic control, demonstration modes and user interface software subsystem*, including the forward and inverse kinematics algorithms of the slave and master demonstration modes and the user displays and input control for the slave robot

A drawing of the interaction between the sub-systems of the RAMS slave robot i. shown on Figure 3,

III. FEATURES

The RAMS master and slave manipulators are six degrees-of-freedom tendon driven robotic arms designed to be compact yet exhibit very precise relative positioning capability. Physically, the slave arm measures 2.5 cm.

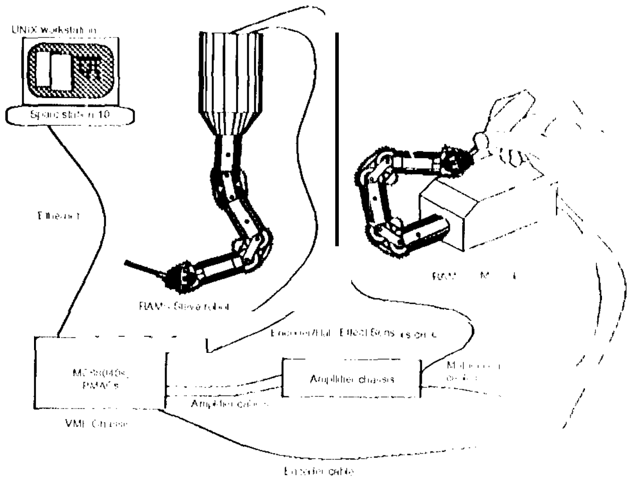

Fig. 2. RAMS system components.

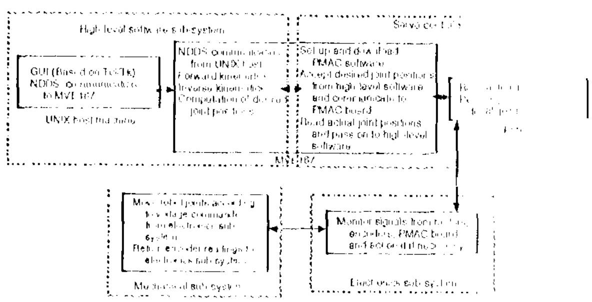

Fig. 3. Interaction between sub-systems of the RAMS telerobot system.

in diameter and is 24.6 cm. long from its base to tip. It is mounted on a cylindrical base housing which measures 11.9 cm. in diameter by 18.0 cm. long containing all of the drives that actuate the arm. The slave arm and base weigh 2.5 kg. The master arm is 2.5 cm. in diameter and 25.0 cm. long. Its base is 10.8 cm. by 18.1 cm by 23.1 cm. The master arm and base weighs 3.6 kg. Both arms allow for the passage of a 0.3 cm. cable through the length of the arm for power, suction or communication. Three of the joints on the master are powered to allow the exertion of force feedback to the surgeon's hand. A unique joint design used on the shoulder and elbow joints of the master and slave arms allow decoupled motion of all joints of the robot. The arms have zero or near zero backlash and low stiction for accurate positioning. The wrist kinematics design based on the kinematics of the Ross-Hime Designs, Inc. OMNI-WRIST [2],[4]. The wrist on the RAMS slave robot is lightweight and has a high load rating. Motors and ... are ... robot arm are easily removable allowing the arm to be sterilized in an autoclave. Graceful shutdown is triggered by a number of fault conditions including unsafe commands, fuse, voltage supply, and processor functioning failures implemented with optically isolated electronics.

Kinematic algorithms developed for the RAMS system are concise, accurate and easily configured. Filtering of tremor in the surgeon's hand has been implemented as a first order low pass filter. For ease of use of the system, a graphical user interface is used to demonstrate a number of manual and autonomous control modes of the robot.

IV. Plans

A number of additional capabilities are planned for implementation on the slave robot. Independent tests will be conducted in the Cleveland Clinic Foundation over the summer of 1996. A demonstration at JPL of the telerobotic system performing a simulated microsurgical procedure will also be conducted concurrently. A force sensor will be mounted on the slave robot in 1997 to measure surgical instrument tissue interaction forces. These force signals will be amplified and fed back to the master arm to enable force-reflected teleoperation. The capability of amplified force feedback to the surgeon will allow the development of improved procedures for microsurgery not currently possible due to limited tactile and kinesthetic sensing.

References

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Acknowledgement

This work was carried out at the Jet Propulsion Laboratory under a contract with the National Aeronautics and Space Administration. The authors are in the Automation and Control Section, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive Pasadena, CA 91109.

The design specifications for the telerobot described in this report were arrived at in discussions with Steve Charles, MD.